



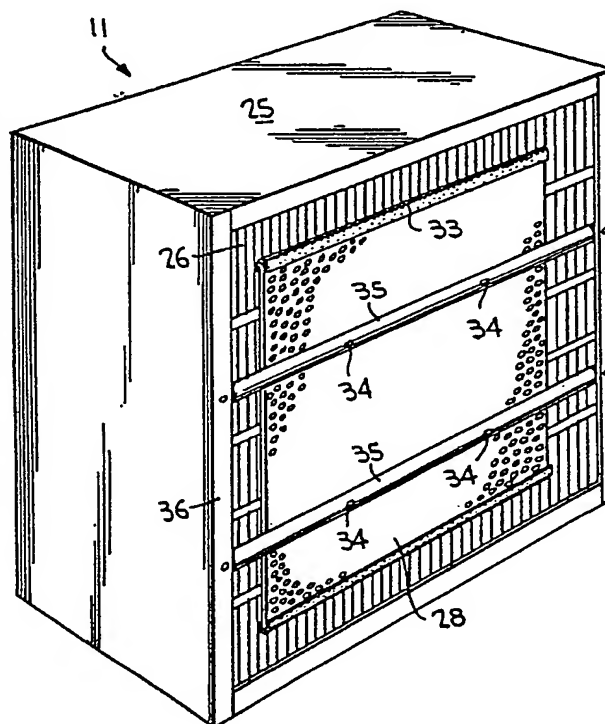
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(54) Title: ELECTRICALLY STIMULATED FILTER METHOD AND APPARATUS

(57) Abstract

An electrically stimulated filter assembly (10) includes a filter unit (11) in which an air gap is maintained between the filter medium (25) and electrodes (27, 28) disposed on opposite sides of that medium thereby preventing degradation of filter efficiency by humid filtered fluid. The filter medium (26) is a sheet like member folded in multiple accordion pleats and disposed between two plate electrodes (27, 28), one of which is grounded to the chassis (25), the other of which is at high voltage. The air gaps (31, 32) are established by insulative plastic combs (29, 30) having bases (29) secured to the electrode plates (27, 28) and teeth (30) projecting from the bases (29) into troughs of the folded filter medium (26). The high voltage plate (28) is on the downstream side of the filter unit (11) and mounted recessed from the downstream opening by insulative tubes (35) secured to both the filter housing (25) and the high voltage plate (28). A precharger (12) is disposed in the assembly (10) upstream of the filter unit (11) and includes plural individual high voltage wires (41) suspended in mutually spaced parallel relation across the flow path. The precharger is housed in a grounded metal frame (40) which is insulated from the wires (41).



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1 ELECTRICALLY STIMULATED FILTER METHOD
2 AND APPARATUS

3 BACKGROUND OF THE INVENTION

4 Technical Field

5 The present invention relates to electrically
6 stimulated filters which operate to remove particles,
7 such as dust, from a fluid, such as air. More
8 particularly, the invention relates to improved filtering
9 and precharging in an electrically stimulated filter
10 assembly.

11 Discussion of the Prior Art

12 Electrically stimulated filters are well known
13 in the prior art. Examples of such filters may be found
14 in the following: U.S. Patent Nos. 2,973,054 (Kurtz);
15 3,242,649 (Rivers), 3,997,304 (Carr), 4,244,710 (Burger),
16 4,279,625 (Inculet, et al.), 4,313,739
17 (Douglas-Hamilton), 4,357,150 (Masuda, et al.) and
18 4,509,958 (Masuda, et al.); Canadian Patent Nos. 821,315

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1 (Inculet) and 821,900 (Incultet, et al.); British Patent
2 No. 892,908; Japanese Patent No. 52,37273; and German
3 Patent Publication 25 32 727. Typically, in the
4 filtering section of the filter assembly, prior art
5 electrically stimulated filters employ electrodes which
6 are in direct contact with the filter medium. This is
7 best illustrated in the Masuda, et al., patents. The
8 filter medium employed is electrically non-conductive and
9 is typically a material such as fiberglass. The amount
10 of current drawn by such electrically stimulated filters
11 is reasonable when the gas to be filtered is at a low
12 relative humidity. However, as the relative humidity of
13 the gas increases, the high voltage current increases
14 exponentially as illustrated by curve A in Figure 13 of
15 the accompany drawings. The ultimate result is either a
16 drop in voltage across the filter unit or a total
17 shut-off of the power applied to the unit. In either
18 case the efficiency of the filter is drastically reduced.
19 The result is unreliable filtering which is the main
20 reason that electrically stimulated filter technology has
21 not gained wide commercial acceptability.

22 Another problem area contributing to the lack of
23 commercial acceptability of prior art electrically
24 stimulated filters relates to the precharger.
25 Prechargers are employed to electrically charge suspended
26 particles in the gas, prior to the filtering stage, so
27 that the charged particles may be more readily separated.
28 A commonly employed prior art precharger, as disclosed in
29 the above-mentioned Masuda, et al., patents, includes

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1 multiple grounded parallel plates with corona wires
2 strung between them. This precharger design results in a
3 high probability of error in achieving wires equispaced
4 from grounded plates. If the wires are not equispaced
5 from the grounded plates, current leaks through a local
6 point resulting in severe reduction in ionization and,
7 thereby, inefficient charging of the suspended particles
8 by the precharger.

9 OBJECTS AND SUMMARY OF THE INVENTION

10 It is therefore an object of the present
11 invention to provide an electrically stimulated filter in
12 which the filtering efficiency is only minimally, if at
13 all, affected by increases in humidity in the fluid
14 medium being filtered.

15 It is another object of the present invention to
16 provide an improved precharger for an electrically
17 stimulated filter in which equispacing from corona wires
18 to the grounded plates is more readily achieved than in
19 prior art precharger units.

20 It is a further object of the present invention
21 to provide an improved electrically stimulated filter
22 assembly in which the aforementioned limitations and
23 disadvantages of the prior art are substantially
24 eliminated.

25 In accordance with the present invention the
26 problem of reduced filtering efficiency in the presence

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1 of high relative humidity is eliminated by separating the
2 electrodes from the filter material by respective air
3 gaps. The air gaps, nominally one-eighth inch in length,
4 permit the current to increase only marginally for
5 relative humidities of up to 100%. In addition, the
6 downstream high voltage electrode employed in the filter
7 is mounted slightly recessed from the downstream end of
8 the filter and electrically isolated from the frame so as
9 to permit the use of a metal frame, thereby reducing
10 labor and material costs.

11 In order to achieve equispacing in an
12 inexpensively manufactured precharger, the precharger is
13 provided in a metal housing frame having grounded
14 perforated plates at its front and back ends and through
15 which the fluid stream to be filtered is caused to flow.

16 Two metal angle beams are suspended on opposite
17 sides of the flow path by ceramic insulators fastened to
18 the metal frame. The corona wires are suspended between
19 the opposed angle beams. The ceramic insulators prevent
20 sparking and current loss from the angle bar to the metal
21 frame of the precharger. The corona wires are suspended
22 by means of springs secured at the ends of the wires to
23 the angle beam. Since the angle bar and the springs have
24 larger dimensions than the corona wires, the angle bars
25 and springs are somewhat closer to the perforated
26 grounded plates at the ends of the housing and can,
27 therefore, be a cause for creating a non-uniform field.
28 In order to circumvent this, these components are
29 shielded by U-shaped covers of plastic insulating
30 material.

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1 BRIEF DESCRIPTION OF THE DRAWINGS

2 These and other objects and advantages of the
3 present invention will become more apparent from the
4 following detailed description and appended claims
5 considered in conjunction with the accompanying drawings
6 wherein like reference numerals are used to designate
7 common elements in the various figures, and wherein:

8 Figure 1 is a side view in elevation of a filter
9 assembly constructed in accordance with the present
10 invention;

11 Figure 2 is a front view in elevation of the
12 assembly of Figure 1;

13 Figure 3 is a view taken along lines 3-3 of
14 Figure 2;

15 Figure 4 is a detailed side view of a portion of
16 the assembly of Figure 1;

17 Figure 5 is a view in perspective of the
18 electrically stimulated filter unit employed in the
19 assembly of Figure 1;

20 Figure 6 is a front view in elevation of the
21 electrically stimulated filter unit of Figure 5;

22 Figure 7 is a side view in elevation, partially
23 broken, of the electrically stimulated filter unit of
24 Figure 5;

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1 Figure 8 is a partial view in vertical section
2 of the electrically stimulated filter unit of Figure 5;

3 Figure 9 is a view in perspective of a portion
4 of the filter unit of Figure 8;

5 Figure 10 is a view in perspective of the
6 pre-charger unit employed in the assembly of Figure 1;

7 Figure 11 is a partial detail view in vertical
8 section of the precharger unit of Figure 10;

9 Figure 12 is a partial front view in elevation
10 of the precharger unit of Figure 10;

11 Figure 13 is a plot of current as a function of
12 relative humidity for a prior art electrically stimulated
13 filter and for the electrically stimulated filter of the
14 present invention; and

15 Figure 14 is a plot of charge versus applied
16 voltage for the prior art electrically stimulated filter
17 and the electrically stimulated filter of the present
18 invention.

19 DESCRIPTION OF THE PREFERRED EMBODIMENTS

20 Referring specifically to Figures 1 through 4 of
21 the accompanying drawings, the filter and precharger
22 units of the present invention may be employed in an
23 overall filter assembly 10 which includes four

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1 electrically stimulated filters 11 and four precharger
2 units 12. Four metal non-electrified pre-filter units 13
3 are employed, each with a respective combination of a
4 precharger 12 and electrically stimulated filter 11, and
5 are also disposed in the housing for assembly 10. Each
6 combination of an electrically stimulated filter 11,
7 precharger 12 and pre-filter 13 is disposed in a
8 respective quadrant of the housing for assembly 10 to
9 provide four respective parallel flow paths through the
10 assembly for the fluid medium to be filtered. In this
11 regard, flow is directed so as to first pass through the
12 pre-filter 13, then through the precharger 12 and finally
13 through the electrically stimulated filter 11 before
14 egressing from assembly 10. Since the individual
15 housings for elements 11, 12 and 13 are metal, all of
16 these housings are at the same potential. This potential
17 is a ground potential established by the metal housing
18 for assembly 10. The downstream side of the electrically
19 stimulated filter unit 11 seals against the frame of the
20 housing for assembly 10 while the precharger unit 12
21 seals against the electrically stimulated filter panel on
22 its upstream side. Similarly, the pre-filter 13 seals
23 against the precharger 12. Each of the four sub-units is
24 inserted through the service doors of the assembly
25 housing and is placed over the threaded rods 14 which
26 are fastened between the metal frames 15a and 15b. The
27 sub-units are then tightened in place by tightening the
28 wing nuts 15 so that the filter unit 11 seals against the
29 frame 15(b) of assembly 10 and the pre-charger 12, seals
30 against filter unit 11, and the pre-filter 13 seals
31 against the pre-charger 12. Note that for each of the
32 four sub-units there are four threaded rods 14, and four

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1 wing nuts 15. This enables each sub-unit to be secured
2 against the frame of assembly 10 as shown in Figure 1. A
3 single high voltage cable 99 from the external high
4 voltage power supply is brought into the assembly 10
5 through an orifice with a grommet 16 (or other well-known
6 sealing means) such that the space between the cable and
7 the orifice is sealed by the grommet 16 and an adhesive
8 as is conventional. This cable 99 is directly connected
9 to metal strip 20 in any one of the four connector
10 assemblies 100 shown in Figure 3. The remaining three
11 connector assemblies are powered by running cable 19 from
12 the powered connector assembly 100 to another connector
13 assembly and so on (as shown in Figure 2) until all four
14 connector assemblies are powered. This distribution of
15 the high voltage power is then provided at the downstream
16 sides of the electrically stimulated filters via
17 connectors 17. These connectors 17 are spring members
18 which serve as connection points between the high voltage
19 wiring and the hot or high voltage electrodes of the
20 electrically stimulated filters. This technique, as best
21 illustrated in Figure 3, eliminates the need for
22 expensive wiring and connectors. The high voltage cable
23 19 is run from the various connectors to the metal plates
24 20 upon which the spring contacts 17 are mounted.
25 Appropriate ceramic insulators 21 are utilized as
26 necessary to support the spring assembly on the housing
27 10 and cable as it is run from sub-unit to sub-unit.

28 Referring specifically to Figures 5-9 of the
29 accompanying drawings, each electrically stimulated
30 filter unit 11 includes a metal square or rectangular

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1 frame 25 having upstream and downstream ends. A filter
2 medium 26 is disposed within the frame 25 and takes the
3 form of a sheet of material having multiple accordion
4 pleats extending transversely of the direction of flow
5 through the frame 25. For purposes of reference, the
6 dimension of the fold lines for the filter medium will be
7 described as lengthwise, whereby the orthogonal
8 dimension, also transverse to the direction of flow, will
9 be described as widthwise. The material for medium 26 is
10 a non-conductive filter medium normally used for the
11 purpose of particulate filtering from gaseous medium. A
12 commonly employed material for this purpose is
13 fiberglass, although other materials may be employed.
14 The accordion pleats are provided to increase the surface
15 area of the filter medium to which the flowing fluid is
16 exposed. Typically, the pleats are approximately four
17 inches to six inches in depth.

18 The upstream end of the filter unit is covered
19 with a perforated metal plate 27 serving as the ground or
20 a low voltage electrode. Electrode plate 27 is grounded
21 by virtue of its contact with the frame portion 25 of the
22 housing. The high voltage electrode is disposed
23 proximate, but slightly recessed from, the downstream end
24 of the filter assembly and comprises a perforated plate
25 28 mounted in a manner described in greater detail
26 hereinbelow.

27 The pleated or convoluted filter medium 26
28 utilizes insulative plastic comb-like spacer members to
29 maintain the pleat spacing and also to maintain an air
30 gap between the filter medium 26 and each of the

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1 electrodes 27 and 28. More specifically, each spacer
2 member includes a base portion 29 from which a
3 multiplicity of teeth 30 project in parallel spaced
4 relation. The base portion 29 is secured against the
5 inside surface of a corresponding perforated electrode
6 plate 27, 28. The base portion 29 blocks only an
7 insignificantly small fraction of the area of the plate
8 so that no meaningful interference with air flow through
9 the plate is produced. The teeth 30 project into
10 respective troughs of the pleated filter medium 26 to
11 thereby maintain the spacing between adjacent pleats.
12 Since the teeth project from both electrodes into the
13 pleats, the pleating is maintained integral from both
14 sides of the filter medium. More importantly, a key
15 function provided by the insulative spacers 29, 30, is
16 the provision of air gaps 31 and 32. Air gap 31 is
17 disposed between the grounded perforated electrode plate
18 27 and the filter medium 26; air gap 32 is provided
19 between the high voltage perforated electrode plate 28
20 and the filter medium 26. These air gaps make it
21 possible to operate the electrostatic filter at high
22 humidities.

23 The high voltage perforated electrode plate 28
24 is smaller on each of its length and width dimensions
25 than the downstream opening in the housing 25 of filter
26 unit 11. Typically, plate 28 is shorter than the frame
27 by three to six inches at each dimension so as to achieve
28 a border of one and a half to three inches of free space
29 around the electrode plate. A plastic jacket is slipped
30 around the edges of the electrode plate 28 so as to
31 further insulate the plate from the frame 25. The

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1 electrode plate is mounted via a pair of screws 34 to
2 respective insulating pipes 35, there being two such
3 pipes employed in the preferred embodiment. These
4 plastic pipes, which may be made of polyvinyl chloride
5 (PVC) are typically three-quarter inch in outside
6 diameter and are secured to the downstream-facing surface
7 of the high voltage electrode plate 28. The pipes are
8 then oriented with their lengths extending widthwise of
9 frame 25 and their ends are secured to the
10 upstream-facing surface of a lip 36 extending from the
11 frame a short distance into the flow path at the
12 downstream end of frame 25. For this purpose, pipes 35
13 are longer than the electrode plate 28 and are
14 sufficiently long to permit them to be secured, by
15 screws, or the like, to the lip 36. Lip 36 is covered
16 with a plastic material for purposes of insulation.

17 It is to be noted that the depth of frame 25
18 (i.e., the dimension in the flow direction) is larger
19 than the depth of the pleats in the filter medium 26.
20 This permits the pipes 35 to be accommodated within the
21 frame. It is to be noted that the screws utilized to
22 secure the pipes 35 to the lip 36 of frame 25 are offset
23 from the screws which secure the electrode plate 28 to
24 the pipes 35. There must be at least a three inch gap
25 between these sets of screws in order to avoid any
26 possibility of sparking. It should also be noted that
27 the plastic tubes 35 can be secured to the plate 28 and
28 to the lip 36 by means of an adhesive material.

29 The air gaps 31 and 32, which are a crucial part
30 of the present invention, are approximately one-eighth

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1 inch in length (i.e., the dimension between the filter
2 medium and the electrode). This spacing is maintained,
3 in the preferred embodiment, by the comb-like structure
4 of the spacers including base 29 and the tapered teeth
5 30. More particularly, the teeth 30 are closer together
6 at their root ends than at their tip ends so that the
7 pleats of the filter medium 26 can be inserted only to a
8 limited depth between the teeth 30. This, plus the depth
9 of the base member 29, establishes the length of the air
10 gap. It should be noted that the particular means for
11 providing the air gap, namely the comb-like members, is
12 the preferred means for achieving the air gap; however,
13 other methods of achieving the air gap spacing may be
14 employed within the scope of the present invention. The
15 important point is that an air gap be provided between
16 the filter medium and the electrodes.

17 In the preferred embodiment eight comb-like
18 members are used with each electrically stimulated filter
19 unit 11, there being four spacers secured to each
20 electrode plate.

21 The lip 36 of the metal frame 25 is covered with
22 an insulating plastic material 37 so that no bare metal
23 surfaces are exposed. A high electrical resistivity
24 insulating hot melt plastic 38, or other adhesive, is
25 poured into the frame 25, on the side of the high voltage
26 electrode 28 in order to seal the filter medium 26 to the
27 frame 25 and thereby prevent bypass of air around the
28 edges of the filter medium. This plastic material 38
29 also ensures at least a one-eighth to one-quarter inch
30 thickness of insulating hot melt to cover all metal

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1 surfaces inside the metal frame 25 on the high voltage
2 side of the filter medium 26. As a result, any
3 possibility of spark discharge from the high voltage
4 electrode to the grounded metal frame is eliminated. The
5 plastic material 37 disposed over lip 36 may be a
6 urethane gasket and is contoured to seal against a
7 bordering frame in the housing for assembly 10.

8 Referring to Figures 10-12 of the accompanying
9 drawings, the precharger 12 includes a metal rectangular
10 frame 40. A plurality of high voltage or corona wires
11 41, preferably made of tungsten, are spaced between one
12 and two inches apart and extend in parallel relation
13 across the flow path through frame 40 at a location which
14 is approximately the center of the depth dimension (i.e.,
15 the dimension between the upstream and downstream ends)
16 of the frame. In the preferred embodiment the wires 41
17 are between 0.005 inch and 0.008 inch in diameter. The
18 high voltage wires 41 are suspended between respective
19 electrically conductive angle beams 42 by means of
20 individual springs 43. A pair of ceramic insulators 44
21 are disposed on each side of frame 40 and have one end
22 secured to the frame by means of a screw 45 and lock
23 washer 46. The ceramic insulators 44 extend into the
24 flow path a distance of approximately two inches,
25 sufficient to prevent sparking between the frame 40 and
26 the angle beam 42 supported at the other end of the
27 insulators. Similar screws 45 and lock washers 46 are
28 employed to secure the angle beam 42 to the inward end of
29 the insulators 44. The angle beam 42 projects a short
30 distance into the flow path and is perforated to receive
31 the coiled tension springs 43 at the various spaced

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1 locations corresponding to the locations of the high
2 voltage wires 41. Perforated ground plates 47 and 48
3 cover the upstream and downstream ends, respectively, of
4 the housing 40 for the precharger and permit air flow
5 through the housing. Perforated plates 47 and 48 are
6 grounded by virtue of their connection directly to the
7 frame 40. With this construction, it is relatively easy
8 to achieve an equal spacing relationship (i.e.,
9 equispacing) between each wire 41 and the two grounded
10 plates 47 and 48. This is because only two grounded
11 plates are employed and further higher gaps between the
12 wires and plates can be utilized. Higher gap values mean
13 that misalignment of the plates becomes a smaller
14 fraction of the total gap, thereby resulting in an
15 effective elimination of local sparking.

16
17 Since the angle bar 42 and springs 43 have
18 larger dimensions/diameters than the individual wires 41,
19 the angle bars and springs are closer to the perforated
20 ground electrodes than are the wires. This can be a
21 cause for a non-uniform field. If this occurs, current
22 may leak through a local point, resulting in a lack of
23 ionization of the particles passing through the
24 precharger with the fluid to be filtered. As a
25 consequence, the effectiveness of the charger would be
26 significantly reduced. In order to circumvent this, the
27 angle bar and spring are shielded by a U-shaped channel
28 member 50 at both ends of the wires 41. The U-shaped
29 channel member has a base portion which is secured to the
30 insulators 44 along with the angle bar 42 by screws 45
31 and lock washers 46. In addition, the plastic U-shaped
32 insulating guard includes two arm members extending

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1 toward the flow path a sufficient distance to cover the
2 angle bar 42 and springs 43. The plastic guard 50
3 thereby prevents a direct arcing path between the angle
4 bar 42 or springs 43 and either of the grounded plate
5 members 47.

6 As noted above, the efficiency of prior art
7 electrically stimulated filter units drops markedly with
8 increases in the relative humidity of the filtered
9 medium. The present invention overcomes this problem by
10 separating the electrodes in filter 11 from the filter
11 material 26 by means of air gaps 31 and 32. These air
12 gaps make the current draw of the electrically stimulated
13 filter of the present invention increase only marginally
14 for relative humidities up to 100%. The effectiveness of
15 the invention, in this regard, is illustrated in Figure
16 13 wherein curve A represents the current versus humidity
17 characteristic for the filter disclosed in the Masuda, et
18 al., patent (4,509,958) referred to above and curve B
19 represents the same parameter for the electrically
20 stimulated filter of the present invention. For the
21 devices tested, the areas of the two filters were equal.
22 It is clear that the current drawn by the present
23 invention (i.e., curve B), in response to increasing
24 relative humidity is significantly lower than that for
25 the Masuda, et al., filter. In general, apart from the
26 contacting or non-contacting electrode design aspect of a
27 filter, the current draw also depends on field strength.
28 In the test which resulted in the plots of Figure 13, the
29 Masuda, et al., filter (curve A) was run at an estimated
30 two KV/cm average field strength (which was not uniform)
31 while the device of the present invention was run at a

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1 1.6 KV/cm field strength. Thus, although there is a
2 difference in field strength, it is not enough to explain
3 the differences in current draw as represented in Figure
4 13. This difference is due to the electrodes in the
5 Masuda, et al., filter having contact with the filter
6 medium whereas the air gaps 31, 32 of the present
7 invention prevent this contact. It should also be noted
8 that in Masuda, et al., one of the electrodes is covered
9 by an electrically insulated film to reduce sparking.
10 Obviously, from curve A in Figure 13, this was not enough
11 to reduce the current draw nearly as effectively as the
12 air gap of the present invention. It should further be
13 noted that, in the present invention, both the high
14 potential and ground electrodes are separated from the
15 filter medium 26 by respective air gaps.

16 With respect to the precharger 12, field
17 uniformity is readily achieved by means of the present
18 invention. It is this field uniformity that provides the
19 precharger with a significant performance improvement
20 over the precharger disclosed in the aforementioned
21 Masuda, et al., patents. This performance improvement is
22 illustrated in the charge versus applied field plot of
23 Figure 14 wherein curve C is a plot for the present
24 invention and curve D is a plot for the Masuda, et al.,
25 precharger. In the Masuda, et al., precharger, if the
26 gap between wires and plates is increased, the number of
27 wires possible in a given size decreases and,-- therefore,
28 the level of charging decreases. Further, due to the
29 simplicity of utilizing only two ground electrodes in the
30 present invention, the present invention is significantly
31 less expensive to fabricate.

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1 It should also be noted that the springs 43 play
2 a significant part in the present invention by
3 maintaining the wires 41 taut and thereby preventing
4 vibration in response to the flow of the fluid medium
5 being filtered.

6 Only one of the angle bars 42 requires
7 connection to the high voltage cable 51 in the precharger
8 12 since the entire assembly, including both angle bars
9 and the wires 41 and springs 43 are floating at the high
10 voltage delivered by cable 51. The cable is provided
11 through an entry point using an insulator connector 52 at
12 a suitable opening in housing 40. The wire is connected
13 to the angle bar at the nearest location on the angle bar
14 at which a screw 45 secures the angle bar to an insulator
15 44.

16 In the preferred embodiment of the precharger,
17 the wires 41 are spaced one inch apart, the insulators 44
18 are one inch long, the angle bar 42 is one-eighth inch
19 thick and has legs one half inch long, the wires 41 are
20 spaced one and 3/8 (three-eighths) inches from each of
21 the grounded plates 47, 48, the ends of the angle bars 42
22 are spaced one and seven-eighth inch from the sides of
23 frame 40, the angle bar is twenty and one-quarter inches
24 long, and the end wires 41 are two inches from the sides
25 of the frame 40. The plastic guard strips 50 extend
26 lengthwise beyond the ends of the angle bars 42 and have
27 a depth sufficient to include the springs 43 and angle
28 bars 42 within the guard channel. In general, any
29 exposed electrically hot (i.e., high voltage) parts, such
30 as the springs 43, angle irons 42, etc. are kept at least

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1 one and one half inches apart from any grounded surface
2 or else are shielded by the guard 50. Only the wires 41
3 are directly exposed to the grounded plates 47 and 48 and
4 are one and a half inches spaced from those plates.

5 The plates 47 and 48 are permanently welded to
6 lips on the metal frame 40.

7 The invention as described herein is an improved
8 electrically stimulated filter and precharger for
9 removing suspended particles from a fluid stream. While
10 the invention has been particularly shown and described
11 with reference to a preferred embodiment thereof, it will
12 be understood by those skilled in the art that various
13 changes in the form and detail may be made without
14 departing from the spirit and scope of the invention.

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1 I CLAIM

2 1. An electrically stimulated filter assembly
3 for separating suspended charged particles from a flowing
4 fluid stream, comprising:

5 a filter housing having an upstream end for
6 admitting said fluid stream into said filter housing, a
7 downstream end for discharging said fluid stream from
8 said filter housing, and a filter flow path through said
9 filter housing from said upstream end to said downstream
10 end;

11 an electrically non-conductive filter means
12 disposed in said filter flow path such that substantially
13 said entire fluid stream passes through said filter
14 means;

15 a first and a second electrode means disposed in
16 said filter housing at the upstream and downstream sides,
17 respectively, of said filter means;

18 a first spacer means for establishing a first
19 air gap preventing physical contact between said first
20 electrode means and said filter means; and

21 a second spacer means for establishing a second
22 air gap preventing physical contact between said second
23 electrode means and said filter means;

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1 whereby filtering efficiency is not
2 significantly affected by increases in humidity in said
3 fluid stream due to the presence of said air gap.

4 2. The electrically stimulated filter assembly
5 according to claim 1 wherein said first and second
6 electrode means are first and second perforated plates,
7 respectively, disposed in said filter flow path to permit
8 said fluid stream to flow through said perforated plates.

9 3. The electrically stimulated filter assembly
10 according to claim 2 wherein said first spacer means
11 comprises at least a first electrically non-conductive
12 spacer member disposed in said filter flow path between
13 said first perforated plate and said filter means, said
14 first spacer member having a cross-sectional area
15 transverse to said filter flow path which is a small
16 fraction of the area of the filter flow path, and wherein
17 said second spacer means comprises at least a second
18 electrically non-conductive spacer member disposed in
19 said filter flow path between said second perforated
20 plate and said filter means, said first spacer member
21 having a cross-sectional area transverse to said filter
22 flow path which is a small fraction of the area of the
23 filter flow path.

24 4. The electrically stimulated filter assembly
25 according to claim 3 wherein said filter housing is a
26 frame of electrically conductive material, wherein said
27 first electrode means is disposed proximate said upstream
28 end in electrically conductive relation to said frame,
29 and wherein said second electrode means is disposed

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1 proximate said downstream end, said assembly further
2 comprising mounting means for securing said second
3 electrode means to said frame in electrically insulated
4 relation to said frame.

5 5. The electrically stimulated filter assembly
6 according to claim 4 wherein said downstream end of said
7 filter housing has an opening of predetermined length and
8 width dimensions;

9 wherein said second perforated plate has length
10 and width dimensions smaller than said predetermined
11 length and width dimensions, respectively; and

12 wherein said mounting means comprises at least
13 one electrically non-conductive support member secured to
14 said frame and to said second plate for supporting said
15 second plate in spaced relation to said frame.

16 6. The electrically stimulated filter according
17 to claim 4 wherein said frame includes a lip at said
18 downstream end projecting radially inward and generally
19 perpendicular to said filter flow path to define a
20 downstream outlet having predetermined length and width
21 dimensions, said lip having upstream and
22 downstream-facing surfaces;

23 wherein said perforated plate has length and
24 width dimensions which are smaller than said
25 predetermined length and width dimensions, respectively;
26 and

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1 wherein said mounting means comprises first and
2 second elongated support members of insulative material
3 having a length slightly greater than said predetermined
4 width but smaller than the width of said frame, said
5 support members having a thickness dimension defined
6 between upstream-facing and downstream-facing sides of
7 said support members, said upstream-facing side being
8 secured to said second perforated plate, said downstream-
9 facing side being secured to said upstream-facing surface
10 of said lip to extend width-wise across said downstream
11 outlet;

12 whereby said second perforated plate is
13 supported within said frame spaced from said downstream
14 outlet by the thickness of said support members.

15 7. The electrically stimulated filter according
16 to claim 6 wherein said support members are respective
17 hollow plastic tubes.

18 8. The electrically stimulated filter according
19 to claim 6 wherein said filter means includes a
20 sheet-like member of filter material arranged in a series
21 of multiple accordion pleats having fold lines oriented
22 along the length dimension of said downstream outlet and
23 defining multiple troughs and peaks;

24 wherein said first spacer means comprises a
25 first plurality of electrically insulative comb-like
26 members having a base portion secured to said first
27 perforated plate and a plurality of spaced teeth
28 extending from said base member and into respective

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1 troughs of said filter means to maintain said pleats in
2 an open state; and

3 wherein said second spacer means comprises a
4 second plurality of electrically insulative comb-like
5 members having a base portion secured to said second
6 perforated plate and a plurality of spaced teeth
7 extending from that base portion and into respective
8 troughs in said filter means to maintain the pleats in an
9 open state.

10 9. The electrically stimulated filter assembly
11 according to claim 2 wherein said filter housing is a
12 frame of electrically conductive material, wherein said
13 first electrode means is disposed proximate said upstream
14 end in electrically conductive relation to said frame,
15 and wherein said second electrode means is disposed
16 proximate said downstream end, said assembly further
17 comprising mounting means for securing said second
18 electrode means to said frame in electrically insulated
19 relation to said frame.

20 10. The electrically simulated filter assembly
21 according to claim 9 wherein said frame includes a lip at
22 said downstream end projecting radially inward and
23 generally perpendicular to said filter flow path to
24 define a downstream outlet having predetermined length
25 and width dimensions, said lip having upstream and
26 downstream-facing surfaces;

27 wherein said perforated plate has length and
28 width dimensions which are smaller than said

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1 predetermined length and width dimensions, respectively;
2 and

3 wherein said mounting means comprises first and
4 second elongated support members of insulative material
5 having a length slightly greater than said predetermined
6 width but smaller than the width of said frame, said
7 support members having a thickness dimension defined
8 between upstream-facing and downstream-facing sides of
9 said support members, said upstream-facing side being
10 secured to said second perforated plate, said downstream-
11 facing side being secured to said upstream-facing surface
12 of said lip to extend width-wise across said downstream
13 outlet;

14 whereby said second perforated plate is
15 supported within said frame spaced from said downstream
16 outlet by the thickness of said support members.

17 11. The electrically stimulated filter assembly
18 according to claim 2 wherein said filter means includes a
19 sheet-like member of filter material arranged in a series
20 of multiple accordion pleats having fold lines oriented
21 along the length dimension of said downstream outlet and
22 defining multiple troughs and peaks;

23 wherein said first spacer means comprises a
24 first plurality of electrically insulative comb-like
25 members having a base portion secured to said first
26 perforated plate and a plurality of spaced teeth
27 extending from said base member and into respective

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1 troughs of said filter means to maintain said pleats in
2 an open state; and

3 wherein said second spacer means comprises a
4 second plurality of electrically insulative comb-like
5 members having a base portion secured to said second
6 perforated plate and a plurality of spaced teeth
7 extending from that base portion and into respective
8 troughs in said filter means to maintain the pleats in an
9 open state.

10 12. The electrically stimulated filter assembly
11 according to claim 1 wherein said filter housing is a
12 frame of electrically conductive metal;

13 wherein said first electrode means is disposed
14 proximate said upstream end in electrically conductive
15 relation to said frame;

16 wherein said electrode means is disposed
17 proximate said downstream end;

18 said assembly further comprising mounting means
19 for securing said second electrode means to said frame in
20 electrically insulated relation to said frame;

21 wherein said downstream end of said filter
22 housing has an opening of predetermined length and width
23 dimensions;

24 wherein said second electrode means has length
25 and width dimensions smaller than said predetermined

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1 length and width dimensions, respectively; and

2 wherein said mounting means comprises at least
3 one electrically non-conductive support member secured to
4 said frame and to said second electrode means to support
5 said second electrode means downstream of said filter
6 means in spaced relation to said frame.

7 13. The electrically stimulated filter assembly
8 according to claim 1 wherein said filter means includes a
9 sheet-like member of filter material arranged in a series
10 of multiple accordion pleats having fold lines oriented
11 along the length dimension of said downstream end and
12 defining multiple troughs and peaks;

13 wherein said first spacer means comprises a
14 first plurality of electrically insulative comb-like
15 members having a base portion secured to said first
16 electrode means and a plurality of spaced teeth extending
17 from said base member and into respective troughs in said
18 filter means to maintain said pleats in an open state;
19 and

20 wherein said second spacer means comprises a
21 second plurality of electrically insulative comb-like
22 members having a base portion secured to said second
23 electrode means and a plurality of spaced teeth extending
24 from that base member and into respective troughs in said
25 filter means to maintain said pleats in an open state.

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1 14. The electrically stimulated filter
2 according to claim 1 further comprising:

3 an assembly housing, said filter housing being
4 disposed in said assembly housing, said assembly housing
5 having an inlet end for receiving said fluid stream and
6 an outlet end for discharging said fluid stream from said
7 assembly housing; and

8 precharger means disposed in said assembly
9 housing upstream of said filter housing for electrically
10 charging said suspended charged particles prior to their
11 entry with the fluid stream into said filter housing.

12 15. The electrically stimulated filter assembly
13 according to claim 14 wherein said precharger means
14 comprises:

15 a metal precharger housing defining a framed
16 flow passage and having open front and back ends, said
17 precharger housing being oriented in said assembly
18 housing to permit flow of said fluid stream through said
19 framed flow passage from the front end to the back end;

20 a plurality of electrically conductive wires;

21 suspension means for suspending each of said
22 wires across said framed flow passage in mutually spaced
23 parallel relation and electrically insulated from said
24 metal precharger housing; and

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1 electrical connector means for applying a high
2 voltage between each of said suspended wires and said
3 metal precharger housing.

4 16. The electrically stimulated filter assembly
5 according to claim 15 wherein said suspension means
6 comprises:

7 first and second electrical insulator means
8 secured to said metal precharger housing at first and
9 second locations, respectively, on opposite sides of said
10 flow passage, each insulator means having a first end
11 secured adjacent said precharger housing and a second end
12 extending transversely into said flow passage;

13 first and second electrically conductive
14 terminal means secured to the second end of said first
15 and second insulator means, respectively; and

16 further means suspending each of said wires
17 between said first and second electrically conductive
18 terminal means and across said flow passage.

19 17. The electrically stimulated filter assembly
20 according to claim 16 wherein said first electrically
21 conductive terminal means comprises a first elongated
22 metal bracket member;

23 wherein said further means comprises a first
24 plurality of individual spring members, one for each of
25 said wires, secured to said first bracket member at

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1 spaced locations along the length of said first bracket
2 member;

3 wherein said second electrically conductive
4 terminal means comprises a second elongated metal bracket
5 member;

6 wherein said further means further comprises a
7 second plurality of individual spring members, one for
8 each of said wires, secured to said second bracket member
9 at spaced locations along the length of said second
10 bracket member; and

11 wherein each of said wires is tautly suspended
12 across said flow passage between respective spring
13 members in said first and second plurality of individual
14 spring members.

15 18. The electrically stimulated filter assembly
16 according to claim 17 further comprising insulative
17 shield means disposed between said spring members and
18 said precharger housing for preventing electrical arcing
19 between said spring members and said precharger housing.

20 19. The electrically stimulated filter assembly
21 according to claim 17 wherein said precharger housing
22 includes an outer frame and front and back perforated
23 metal screen members disposed over said front and back
24 ends, respectively, in electrically conductive contact
25 with said outer frame;

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1 said precharger means further comprising
2 insulative shield means disposed between said spring
3 members and said screen members.

4 20. The electrically stimulated filter assembly
5 according to claim 19 wherein said insulative shield
6 means comprises first and second plastic generally
7 U-shaped channels having a base portion secured to said
8 second end of said first and second electrical insulator
9 means, respectively, and having first and second leg
10 portions extending toward said flow passage in front of
11 and in back of said spring members.

12 21. The electrical filter assembly according to
13 claim 16 wherein said precharger housing includes an
14 outer frame and front and back perforated metal screen
15 members disposed over said front and back ends,
16 respectively, in electrically conductive contact with
17 said outer frame;

18 said precharger means further comprising first
19 and second plastic generally U-shaped channels having a
20 base portion secured to said second end of said first and
21 second electrical insulator means, respectively, and
22 having first and second leg portions extending toward
23 said flow passage in front of and in back of said further
24 means.

25 22. The electrically stimulated filter assembly
26 according to claim 16 wherein said first and second
27 electrode means are first and second perforated plates,

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1 respectively, disposed in said filter flow path to permit
2 said fluid stream to flow through said perforated plates.

3 23. The electrically stimulated filter assembly
4 according to claim 22 wherein said first spacer means
5 comprises at least a first electrically non-conductive
6 spacer member disposed in said filter flow path between
7 said first perforated plate and said filter means, said
8 first spacer member having a cross-sectional area
9 transverse to said filter flow path which is a small
10 fraction of the area of the filter flow path, and wherein
11 said second spacer means comprises at least a second
12 electrically non-conductive spacer member disposed in
13 said filter flow path between said second perforated
14 plate and said filter means, said first spacer member
15 having a cross-sectional area transverse to said filter
16 flow path which is a small fraction of the area of the
17 filter flow path.

18 24. The electrically stimulated filter assembly
19 according to claim 22 wherein said filter housing is a
20 frame of electrically conductive metal;

21 wherein said first electrode means is disposed
22 proximate said upstream end in electrically conductive
23 relation to said frame;

24 wherein said electrode means is disposed
25 proximate said downstream end;

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1 said assembly further comprising mounting means
2 for securing said second electrode means to said frame in
3 electrically insulated relation to said frame;

4 wherein said downstream end of said filter
5 housing has an opening of predetermined length and width
6 dimensions;

7 wherein said second electrode means has length
8 and width dimensions smaller than said predetermined
9 length and width dimensions, respectively; and

10 wherein said mounting means comprises at least
11 one electrically non-conductive support member secured to
12 said frame and to said second electrode means to support
13 said second electrode means downstream of said filter
14 means in spaced relation to said frame.

15 25. The electrically stimulated filter assembly
16 according to claim 23 wherein said filter means includes
17 a sheet-like member of filter material arranged in a
18 series of multiple accordion pleats having fold lines
19 oriented along the length dimension of said downstream
20 end and defining multiple troughs and peaks;

21 wherein said first spacer means comprises a
22 first plurality of electrically insulative comb-like
23 members having a base portion secured to said first
24 electrode means and a plurality of spaced teeth extending
25 from said base member and into respective troughs in said
26 filter means to maintain said pleats in an open state;
27 and

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1 wherein said second spacer means comprises a
2 second plurality of electrically insulative comb-like
3 members having a base portion secured to said second
4 electrode means and a plurality of spaced teeth extending
5 from that base member and into respective troughs in said
6 filter means to maintain said pleats in an open state.

7 26. An electrically stimulated filter assembly
8 for separating suspended charged particles from a flowing
9 fluid stream, comprising:

10 a filter housing having an upstream end for
11 admitting said fluid stream into said filter housing, a
12 downstream end for discharging said fluid stream from
13 said filter housing, and a filter flow path through said
14 filter housing from said upstream end to said downstream
15 end, said filter housing being of an electrically
16 conductive metal material;

17 an electrically non-conductive filter means
18 disposed in said filter flow path such that substantially
19 said entire fluid stream passes through said filter
20 means;

21 a first and second electrode means disposed in
22 said filter housing on opposite sides of said filter
23 means, said first electrode means being disposed
24 proximate said upstream end, said second electrode means
25 being disposed proximate said downstream end;

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1 a first terminal means for applying a ground
2 potential to said first electrode means and to said
3 filter housing;

4 a second terminal means for applying a high
5 voltage relative to ground to said second electrode
6 means; and

7 a means establishing an air gap preventing
8 physical contact and providing electrical isolation
9 between said second electrode means and said filter
10 means;

11 whereby filtering efficiency is not
12 significantly affected by increases in humidity in said
13 fluid stream due to the presence of said air gap.

14 27. The electrically stimulated filter assembly
15 according to claim 26 wherein said first and second
16 electrode means are first and second perforated plates,
17 respectively, disposed in said filter flow path to permit
18 said fluid stream to flow through said perforated plates.

19 28. The electrically stimulated filter assembly
20 according to claim 27 wherein said means establishing an
21 air gap comprises an electrically non-conductive spacer
22 member disposed in said filter flow path between said
23 second perforated plate and said filter means, said
24 spacer member having a cross-sectional area transverse to
25 said filter flow path which is a small fraction of the
26 area of said filter flow path.

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1 29. The electrically stimulated filter
2 according to claim 27 wherein said filter means is a
3 sheet-like member of filter material arranged in a series
4 of multiple accordion pleats having fold lines oriented
5 along the length dimension of said downstream end and
6 defining multiple troughs and peaks;

7 wherein said spacer member comprises a comb-like
8 member having a base portion secured to said second
9 perforated plate and a plurality of teeth extending from
10 said base member into respective troughs in said filter
11 means to maintain said pleats in an open state.

12 30. In an electrically stimulated filter
13 assembly for separating suspended charged particles from
14 a flowing fluid stream, a precharger for electrically
15 charging the suspended particles, said precharger
16 comprising:

17 a metal precharger housing having a framed flow
18 passage and having front and back ends, said precharger
19 housing being oriented to permit flow in a predetermined
20 direction of said fluid stream through said framed flow
21 passage from said front end to said back end;

22 a plurality of electrically conductive wires;

23 a suspension means for suspending each of said
24 wires across said framed flow passage in mutually
25 parallel relation. said suspension means being
26 electrically insulated from said metal precharger
27 housing;

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1 a means for applying a high voltage disposed
2 between each of said suspended wires and said metal
3 precharger housing;

4 a first ground plate adjacent said front end of
5 said precharger housing disposed generally
6 perpendicularly to said predetermined direction; said
7 first ground plate being perforated such that particles
8 in the fluid stream pass therethrough;

9 a second ground plate adjacent said back end of
10 said precharger housing disposed generally
11 perpendicularly to said predetermined direction; said
12 second ground plate being perforated such that particles
13 in the fluid stream pass therethrough;

14 whereby, due to passage of particles through
15 said perforations in said first and second ground plates,
16 the particles are exposed to maximum ionization flux on
17 leading and trailing sides thereof.

18 31. The precharger according to claim 30
19 wherein said suspension means comprises:

20 first and second electrical insulator means
21 secured to said metal precharger housing at first and
22 second locations, respectively, on opposite sides of said
23 flow passage, each insulator means having a first end
24 secured adjacent said precharger housing and a second end
25 extending transversely into said flow passage;

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1 first and second electrically conductive
2 terminal means secured to the second end of said first
3 and second insulator means, respectively; and

4 further means suspending each of said wires
5 between said first and second electrically conductive
6 terminal means and across said flow passage.

7 32. The precharger according to claim 31
8 wherein said first electrically conductive terminal means
9 comprises a first elongated metal bracket member;

10 wherein said further means comprises a first
11 plurality of individual spring members, one for each of
12 said wires, secured to said first bracket member at
13 spaced locations along the length of said first bracket
14 member;

15 wherein said second electrically conductive
16 terminal means comprises a second elongated metal bracket
17 member;

18 wherein said further means further comprises a
19 second plurality of individual spring members, one for
20 each of said wires, secured to said second bracket member
21 at spaced locations along the length of said second
22 bracket member; and

23 wherein each of said wires is tautly suspended
24 across said flow passage between respective spring
25 members in said first and second plurality of individual
26 spring members.

1 33. The precharger according to claim 32
2 wherein said precharger housing includes an outer frame
3 and front and back perforated metal screen members
4 disposed over said front and back ends, respectively, in
5 electrically conductive contact with said outer frame;

6 said precharger means further comprising
7 insulative shield means disposed between said spring
8 members and said screen members.

9 34. The precharger according to claim 33
10 wherein said insulative shield means comprises first and
11 second plastic generally U-shaped channels having a base
12 portion secured to said second end of said first and
13 second electrical insulator means, respectively, and
14 having first and second leg portions extending toward
15 said flow passage in front of and in back of said spring
16 members.

17 35. In the assembly of claim 34, a filter unit
18 comprising:

19 a filter housing having an upstream end for
20 admitting said fluid stream into said filter housing, a
21 downstream end for discharging said fluid stream from
22 said filter housing, and a filter flow path through said
23 filter housing from said upstream end to said downstream
24 end, said filter housing being of an electrically
25 conductive metal material;

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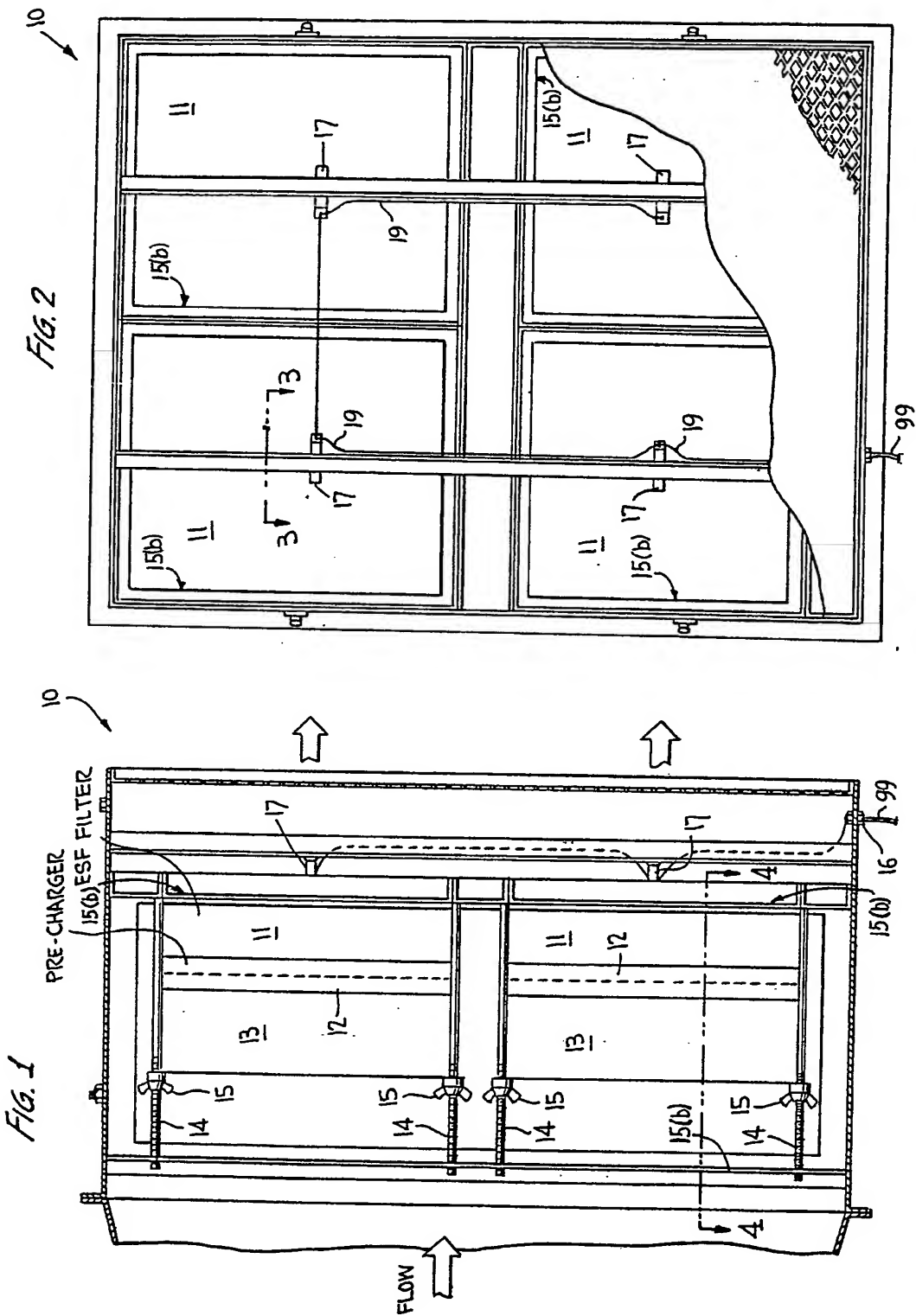
1 electrically non-conductive filter means
2 disposed in said filter flow path such that substantially
3 said entire fluid stream passes through said filter
4 means;

5 first and second electrode means disposed in
6 said filter housing on opposite sides of said filter
7 means, said first electrode means being disposed
8 proximate said upstream end, said second electrode means
9 being disposed proximate said downstream end;

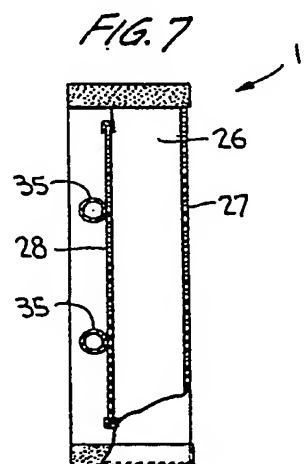
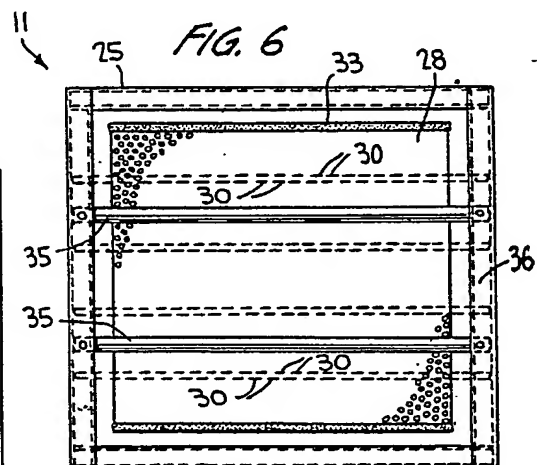
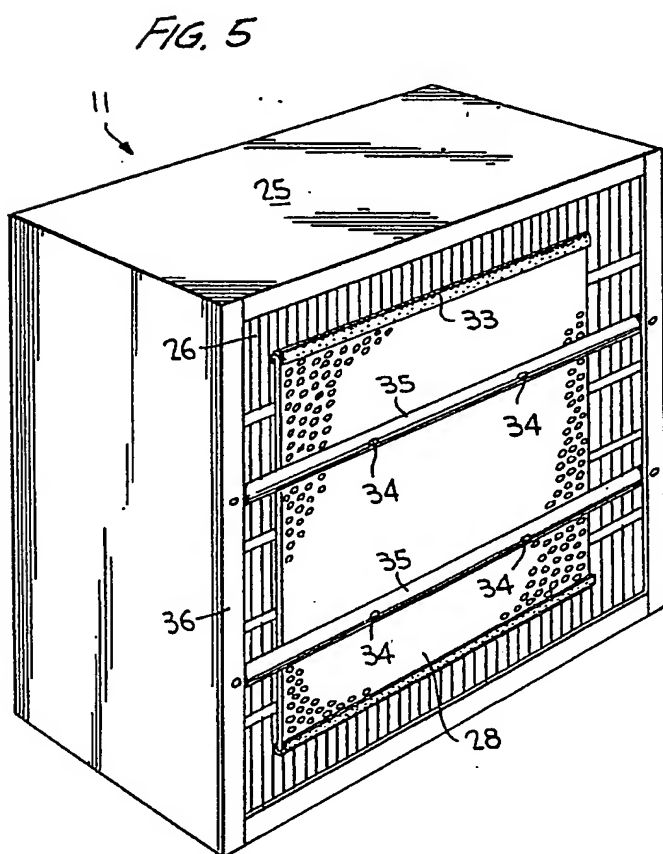
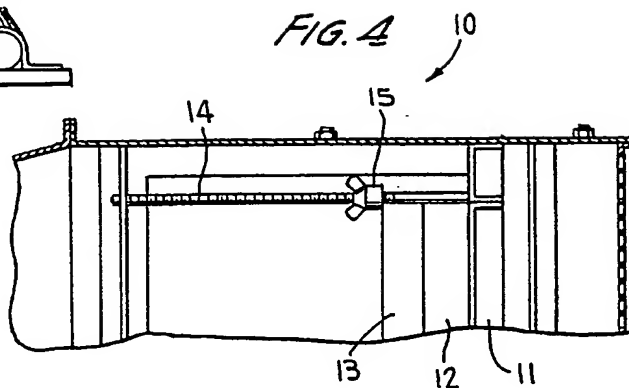
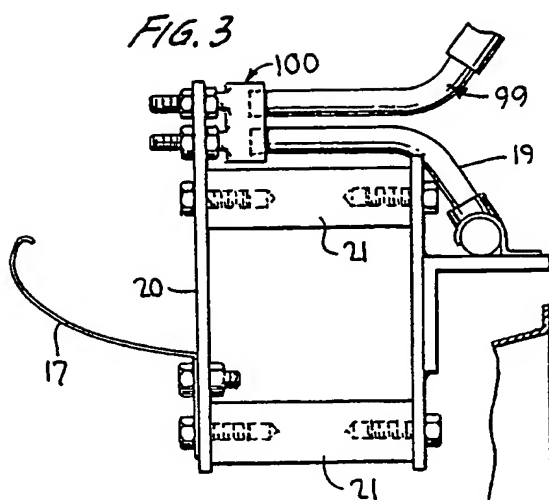
10 first terminal means for applying a ground
11 potential to said first electrode means and to said
12 filter housing;

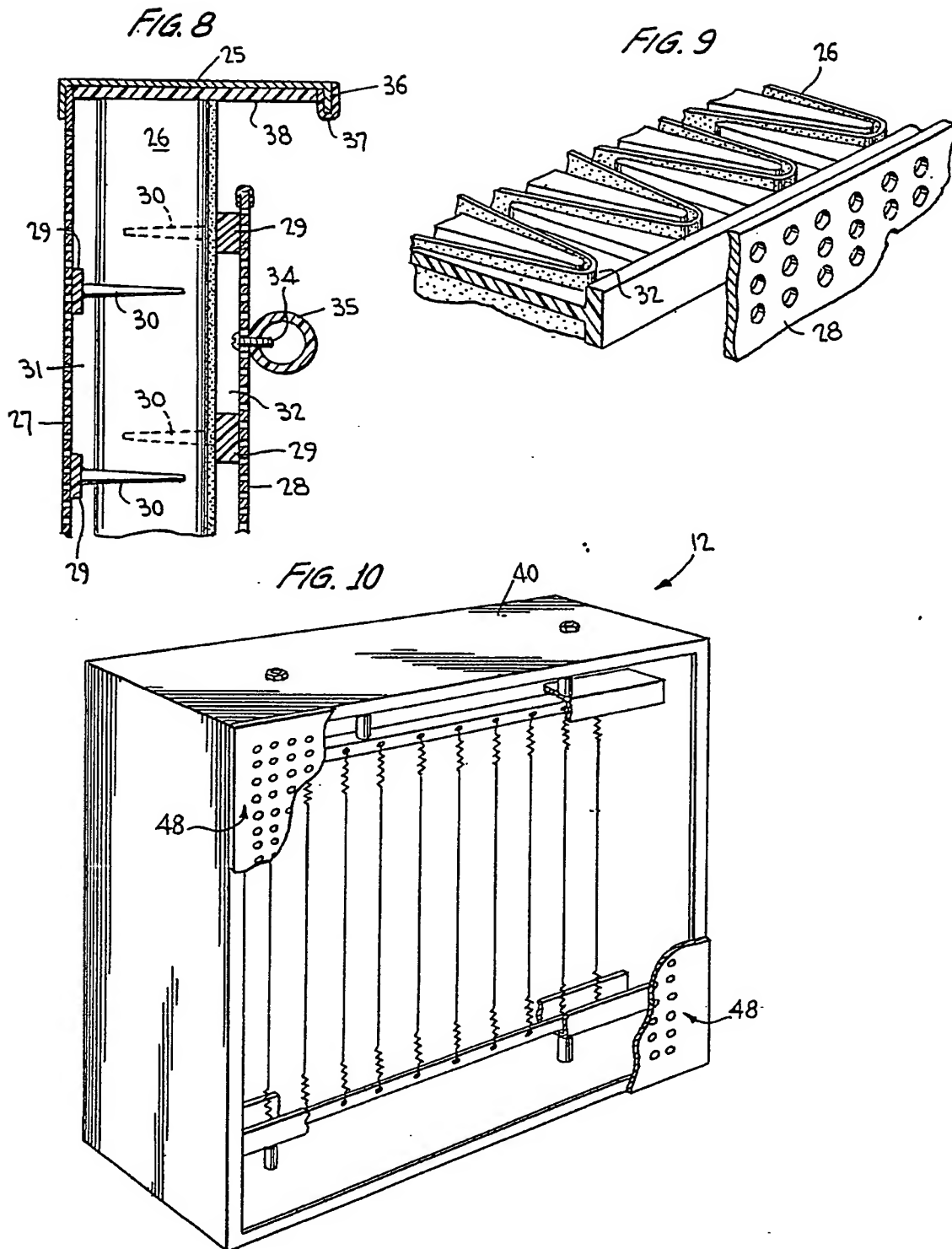
13 second terminal means for applying a high
14 voltage relative to ground to said second electrode
15 means; and

16 means establishing an air gap preventing
17 physical contact and providing electrical isolation
18 between said second electrode means and said filter
19 means.



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FIG. 11

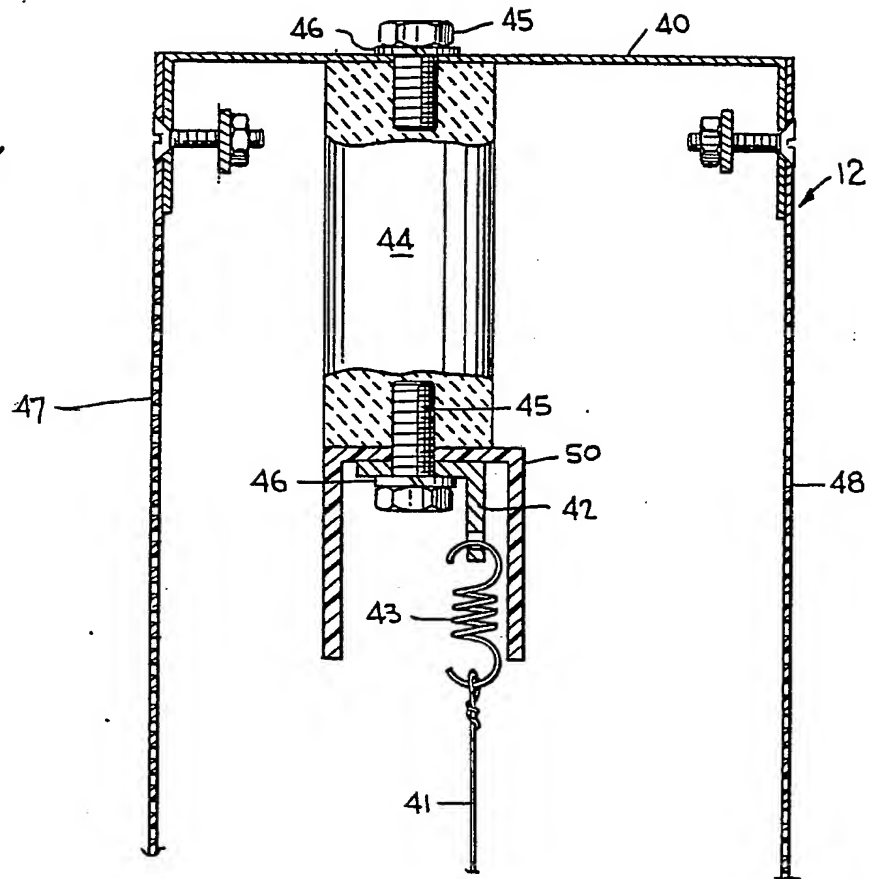
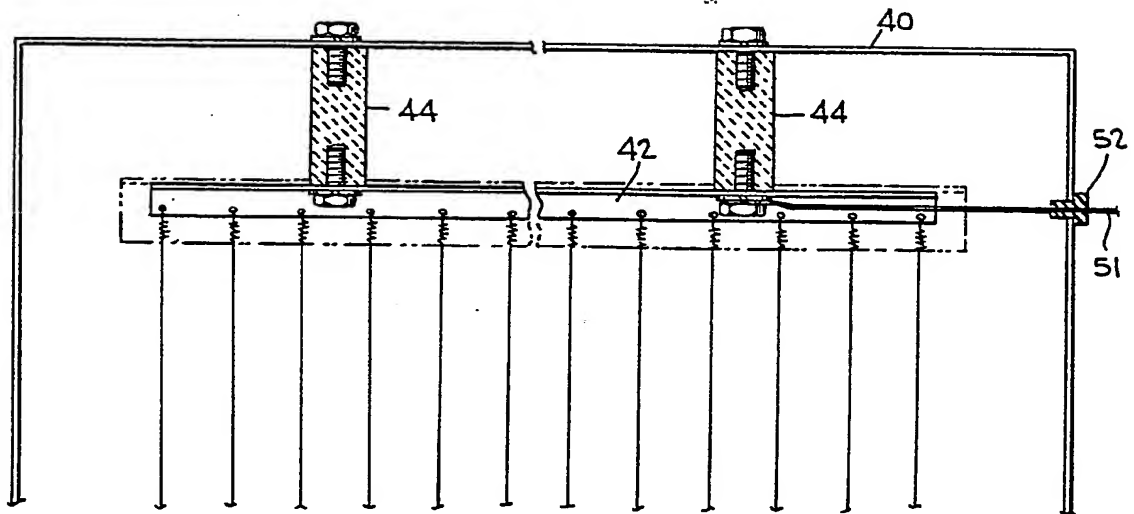


FIG. 12



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FIG. 13

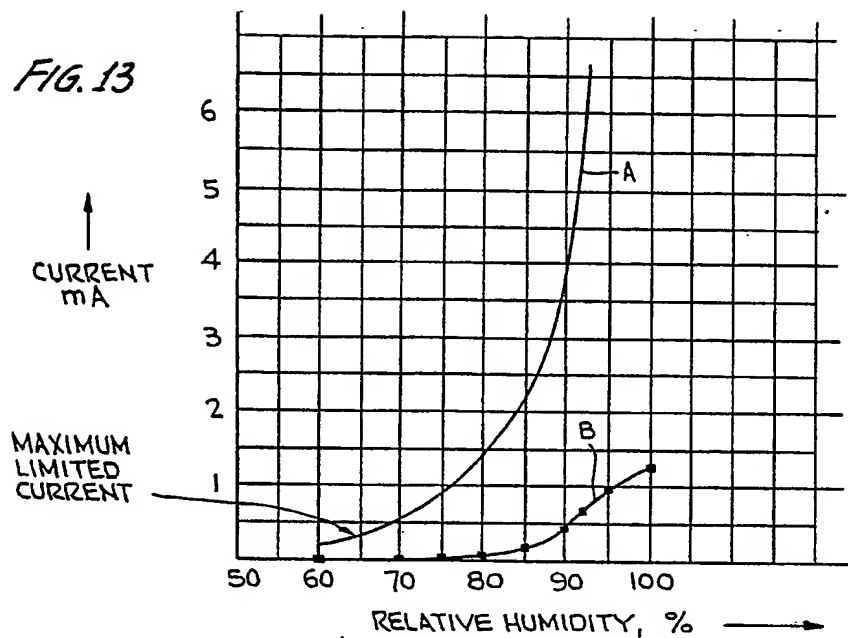
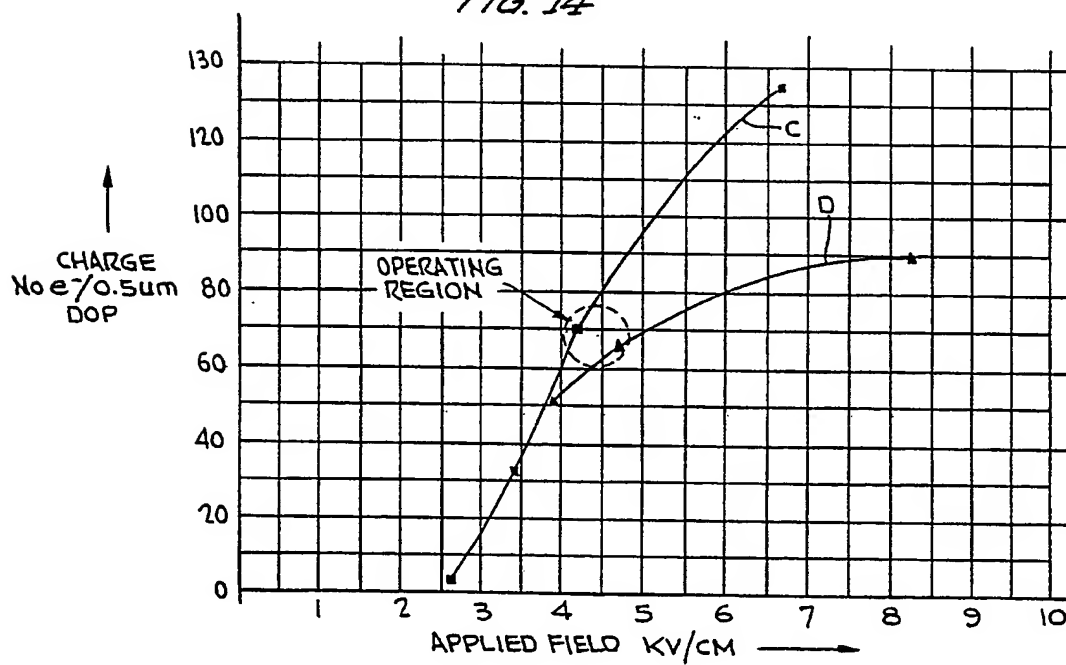


FIG. 14



INTERNATIONAL SEARCH REPORT

International Application No **PCT/US86/01910**

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ³		
According to International Patent Classification (IPC) or to both National Classification and IPC		
US 55/132, 55/151		
Int CL.(4) B03C 3/09		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁴		
Classification System	Classification Symbols	
U.S.	55/132, 55/138, 55/146, 55/148, 55/151	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁵		
III. DOCUMENTS CONSIDERED TO BE RELEVANT ¹⁴		
Category ⁶	Citation of Document, ¹⁰ with Indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No. ¹⁸
X	US, A, 3,537,238 (DUNGLER) 03 November 1970 SEE FIGURE 2 AND COLUMN 3 LINES 1-8	1-7, 9, 10 12, 14, 26-28
Y	US, A, 4,509,958 (MASUDA ET AL) 09 April 1985 SEE FIGURES 16 AND 22 AND COLUMN 8 LINES 50-59 AND COLUMN 9 LINES 32-40	1-7, 9, 10 12, 14, 26-28
X	US, A, 4,007,024 (SALLEE ET AL) 08 February 1977 SEE FIGURES 2 AND 3 COLUMN 3 LINE 46 TO COLUMN 4 LINES 1-4	30-35
<div style="display: flex; justify-content: space-between;"> <div style="width: 48%;"> <p>¹⁵ Special categories of cited documents:</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="width: 48%;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&" document member of the same patent family</p> </div> </div>		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search ¹	Date of Mailing of this International Search Report ²	
27 October 1986	07 NOV 1986	
International Searching Authority ¹	Signature of Authorized Officer ²⁰	
ISA/US	<i>Bernard Nozick</i> Bernard Nozick	

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